DOCUMENT RESUME

ED 346 843 IR 015 627

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TITLE Digital Advances in Contemporary Audio Production.
PUB DATE May 91
NOTE 19p.; Paper presented at the Annual Meeting of the Wisconsin Communication Association (Madison, WI, May 1991).
PUB TYPE Reports - Descriptive (141) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS *Audio Equipment; Audiotape Recordings; *Broadcast Industry; Microcomputers; *Optical Data Disks; *Technological Advancement
IDENTIFIERS *Digital Technology; *Workstations

ABSTRACT

Noting that a revolution in sonic high fidelity occurred during the 1980s as digital-based audio production methods began to replace traditional analog modes, this paper offers both an overview of digital audio theory and descriptions of some of the related digital production technologies that have begun to emerge from the mating of the computer microchip with components of the traditional audio production process. Digital recording is explained as the process of describing sound in terms of numbers as the voltage changes created by the microphone are converted by way of an analog-to-digital converter to digital information that can be manipulated like any other computer data. MIDI (Musical Instrument Digital Interface) is cited as one of the first applications of digital recording technology. Digital audio production components are then described, they are: (1) the compact disk family, which includes WORMs, the recordable compact disk; (2) digital audio tape (DAT) cassettes; (3) digital audio workstations (DAW); and (4) 3-D audio and digital audio broadcasting (DAB). These descriptions include discussions of technical and policy issues associated with the use of these technologies. (16 references) (BBM)

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Digital advances in contemporary audio production

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Presented at the annual meeting of the
Wisconsin Communication Association
May, 1991
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Digital advances in contemporary audio production

During the 1980s, a revolution in sonic high fidelity occurred as digital-based audio production methods began to replace traditional analog modes. The rapid public acceptance of the compact disc was perhaps the most visible manifestation of this "revolution."

As the compact disc has become increasingly commonplace, a host of related digital production technologies have began to emerge from the mating of the computer microchip with components of the traditional audio production process. This article offers both an overview of digital audio theory and describes some of the newest digital audio production components.

THEORY

Digital audio theory

Opcode Systems, Incorporated (1991) offered this succinct explanation of the differences between older analog magnetic recording techniques and newer digital methods:

"Analog recording uses the microphone to pick up sound waves and convert them to continuous voltage changes that can be recorded on a tape deck as patterns of magnetization. These patterns are *analogous* to the original signal, i.e., they are magnetic representations of the physical waveform. Because the magnetic patterns are converted back to voltages when the recording is

played back, some degree of sound degradation occurs and audible noise is the result.

"Digital recording, in general, is the process of describing sound in terms of numbers. In digital recording, the voltage changes created by the microphone are converted to digital information or numbers by way of an analog-to-digital (A-D) converter. The digital audio information can then be stored in memory, on disk, or on tape like any other computer data. During playback, the numbers are translated back to the exact voltages with a digital-to-analog (D-A) converter.

"Because any modification of the digital information is done by simply manipulating numbers, little or no noise or distortion is added to the recording" (Opcode systems, 1991, p. 12).

Two kinds of information about these voltages must be converted to numeric storage and back by the A-D and the D-A converters: frequency, or pitch, information and amplitude, or loudness, information.

Frequency information is converted through *sampling* processes that typically operate at a rate of 44.1 or 48 kiloHertz. The pitch information of an acoustic wave thus is sampled once every 44,100th of a second for compact discs; for digital audio tape, pitch information is sampled once every 48,000ths of a second.

Amplitude information is converted through

quantization processes based on the number of bits the digital processor can use: An 8-bit system would use 2^8 (or 256) quantization intervals. By comparison, a better 16-bit system would use 2^{16} (or 65,536) increments.

Pohlmann (1985), in fact, refers to sampling and quantization as the "twin pillars of audio digitization" (p. 37). His *Principles of digital audio* offers an extensive discussion of these two important processes.

To summarize, the key point of digital audio recording technology lies in its treatment of acoustic sound as a type of *"information."* By regarding sound as just another kind of data, changes to it (via signal processing, editing, and so on) may be accomplished with ease by using a computer. Just as word processing software allows great flexibility over a typewriter in the manipulation of printed text, an audio "text" may be similarly rearranged, added to, deleted, and changed in ways that would be time-consuming or nearly impossible using conventional analog methods.

MIDI: Musical Instrument Digital Interface

One of the first applications of digital recording technology involved musicians who saw new digital techniques as a means of extending the boundaries of what was possible with conventional "analog" musical instruments. To avoid confusion, especially since

contemporary music production takes place in a multitrack recording environment, a standardized protocol was necessary to ensure compatible communication between hybridized electronic musical instruments.

MIDI, or Musical Instrument Digital Interface, was proposed by Dave Smith of Sequential Circuits in the early 1980s (Beatty, 1991). By 1984, MIDI was accepted as a viable protocol to allow various pieces of electronic musical gear to communicate with each other in a standardized way.

"Each MIDI-equipped instrument usually contains a receiver and a transmitter; some may contain one or the other. The receiver accepts messages in MIDI format and executes MIDI commands. The transmitter originates messages in MIDI format and transmits them. MIDI translates actions made at one instrument or device into messages that are sent to another instrument or device" (Alten, 1990, p. 450).

The brain of the MIDI studio is the sequencer, which resembles a multitrack recorder in its ability to receive data from various MIDI devices and store it as separate "tracks" with its memory. Once the information resides in memory, it can be edited or transmitted to other MIDI instruments for playback (Alten, p. 451).[1]

DIGITAL AUDIO PRODUCTION COMPONENTS

The compact disc family

Most consumers identify the term "compact disc" exclusively with audio recordings. Although compact audio (CD-A) discs are perhaps the most prominent exemplars of optical disc technology, they are far from being the only ones. In fact, an entire family of compact discs exists which includes compact audio (CD-A) and CD-3, CD-V, CD+G/M, CD-ROM, and CD-I. Each is discussed briefly in turn.

The familiar audio compact disc itself exists in at least two formats: the standard 120 millimeter (5-inch) format and a smaller 3-inch format called CD-3, which is now officially defunct (Pohlmann, 1989, p. 42) despite initially strong sales in Japan. A standard compact audio (CD-A) is capable of some 74 minutes of stereo audio storage and offers a signal-to-noise ratio of beyond 98 deciBels.[2]

Once consumer acceptance was assured, record producers saw utility in offering compact discs encoded with one or more music videos related to the recording group's audio. This CD-V format requires a special compact disc player in order to see the music video and has yet to enjoy widespread popularity. Part of the drawback is the economics involved with purchasing a separate player component to see the CD-Vs; the CD-V discs themselves have

higher retail prices than non-video CD-As. Video also requires more information storage space, which does not allow more than one or two videos to be encoded per disc, making the investment in a special player seem even more dubious. Where the CD-V has enjoyed its greater success has been as a revived videodisc sporting prerecorded motion pictures in a larger diameter disc format.[3]

CD+G/M is a combination of two formerly distinct formats of interest to musicians. CD+G offered on-screen graphics to add to a musical group's recording aesthetic, song lyrics in different languages, or guitar chords. CD+M offered compact discs encoded with MIDI software for applications "such as control of MIDI instruments or other music processors, music minus one, reorchestration by users, printing or display of a score and creation of a personal music database" (Pohlmann, 1989, p. 42). As with CD-V, a unique playback device is required to access information beyond the stereo audio.

CD-ROM (for Read Only Memory) is becoming more and more familiar to library users as a storage and access medium for vast quantities of information. Card catalogs, database materials, and entire encyclopedias are being written to CD-ROM, which also requires a unique playback device.

CD-I is perhaps the most ambitious member of the compact disc family. "Merging motion video, digital

audio, text, graphics, animation, database, and interactive software on a single compact disc has proved to be stimulating and challenging to its designers," Pohlmann (1990) noted with considerable understatement. During June, 1990, a London CD-I conference previewed many of the new tools and titles that were to have been set for a 1991 launch of the format, even though the theory and technology have existed for several years. Although the format holds great promise, public reaction is as yet unknown.

WORMs: The recordable compact disc

One of the newest development in digital audio recording has been the debut of the recordable compact disc. Previously, compact discs existed as playback devices only. Technology developed by Tandy Corporation and others allows the possibility of recording any material, digital or analog, directly to compact disc. These optical recording media have acquired the acronym WORM (Write Once - Read Many). The central idea is that once a recording is made to one of these discs, it is permanently fixed there and then can only be used for playback.

Audio purists exhibit a certain ambivalence about this possibility, since one of the most visible attributes of the mass enthusiasm for compact discs was its early emphasis on high fidelity. With recordable CDs, it is

conceivable that someone could record inferior audio (for example, one's aging collection of badly-scratched 45 rpm vinyl singles) to compact disc along with all the scratches, hisses, pops and skips that accompany the original recording. This is seen as a dilution of the recording integrity that has become synonymous with the compact disc.

The other problem is recording piracy. Once perfect duplication is possible, a number of recording artists and their production companies stand to lose multiple millions in lost royalties if recordable compact discs could be erased and rerecorded over and over again with maximum fidelity each time. This is a problem that also has plagued the introduction of digital audio tape (DAT).

DAT and DCC: Cassette formats in search of an audience

The recordable compact disc introduces yet another competitor into what has become a very confused digital recording arena. Digital audiotape (DAT) exists in both reel and cassette formats, with the former aimed at the professional studio recording user, the latter primarily aimed at the home consumer. The format can use either a stationary or a rotating magnetic recording head; hence, the use of the terms S-DAT and R-DAT to distinguish between them.

Proponents of R-DAT cassettes unwittingly invited what has become an endless wrangling over the contribution of

R-DAT's superior sonic fidelity to the home taping and piracy problem. Throughout much of the 1980s, various technical solutions were advanced in an effort to defeat copying of compact discs onto digital cassette tape, mainly through the use of notch filtering and subcode generation. Unfortunately, decreases in high fidelity were often the result.

The resolution of this dilemma has slowed the introduction of R-DAT cassettes into the United States consumer market as Congress continues to mull over legislation aimed at allowing reasonable copying privileges for the average consumer while guarding against unauthorized piracy of copyrighted performances. One recent compromise would allow an R-DAT tape to be made from a compact disc but would prohibit tape-to-tape copying thereafter.

Additionally, the R-DAT cassette itself is not compatible with standard analog cassette tapes. On average, R-DAT cassettes are slightly larger and hold approximately two hours of information on only one side of the cassette.

The digital compact cassette (DCC), by contrast, would allow a potential user to choose either analog or digital recording and playback modes. This technology offers compatibility between digital cassettes and analog cassettes, which is seen as perhaps an important

consideration for the home consumer, most of whom have many prerecorded analog music tapes that would still be usable with a DCC playback deck. If DCC succeeds in overcoming the same copyright protection problems that have plagued R-DAT, it may well become the format of choice for the home consumer, leaving the R-DAT format to the broadcast and recording field professional (De Lancie, 1991).

DAW: Digital Audio Workstations

The digital audio workstation (DAW) offers an integrated computer-controlled approach to digital production, editing, and mixing at a central location.

"Most audio workstations have a central computer with integrated, multifunctional hardware and software that allow general-purpose computing, signal processing, real-time synthesis and interaction, and random access retrieval, as well as containing various input and output devices and vast information storage capacity" (Alten, 1990, p. 61-63).

One of the better known DAWs is made by Studer-ReVox, the Editech Dyaxis (Hodas, 1990). The Dyaxis uses an Apple Macintosh which runs custom-developed MacMix software. The Dyaxis system is modular, which allows both flexibility to suit user needs as well as expandability.

"The Dyaxis has uses that cover all the varied audio fields of recording, broadcast, video and film production/

postproduction, and CD premastering. It is a powerful tool with sophisticated time code capabilities, high quality audio and ergonomic screens that make the operating process simple and quick to learn" (Hodas, p. 120).

Briefly, the Dyaxis offers an Audio Processor rack, which interfaces between the Macintosh and the rest of the Dyaxis hardware. It is the heart of the Dyaxis system in that it offers a variety of input-output options. Dyaxis also features a System Synchronizer which adds full-feature time code reading and writing capability between different timecode standards such as MIDI for music and SMPTE/EBU for television and film. The Mass Storage System stores the sound information on hard disks capable of storing up to six hours of stereo audio.

The number of digital formats accepted by the Dyaxis perhaps indicates just how complicated standardization has become within the digital audio arena. The Dyaxis is capable of accepting information from formats such as SPDIF, AES/EBU (Audio Engineering Society/European Broadcasting Union), SDIF-2, PCM-601 (Pulse Code Modulation), Yamaha stereo, PD (ProDigi) and DASH (Digital Audio Stationary Head).

What's next? 3-D audio and DAB

Two recent developments in audio processing promise to make an impact on the use of digital for audio recording:

the renewed quest for three-dimensional audio and Digital Audio Broadcasting (DAB).

As Daley (1990) observed, there have been few advances in the human perception of sound since the initial debut of stereo sound in the early 1960s. The few attempts, such as the quadraphonic movement of the 1970s, were failures largely due to lack of consumer enthusiasm or a failure to establish compatible standards.

The renewed emphasis on three-dimensional sound has been given impetus from the motion picture industry, whose quest to impart greater sonic realism to films has led to advances such as SurroundSound. Consumers renting videocassette versions of the films have come to expect a high level of sonic detail in film; hence, a burgeoning market for more sonic detail in conventional audio recordings has been a logical outgrowth.

Cohen (1990) points out that "the term '3-D sound' is often used quite randomly to describe a wide range of technologies, some of which has explicitely different aims and capacities...What all these technologies share is the desire to improve the accurate and natural reproduction of spatial environments. Advances in our understanding of psychoacoustics and the advent of digital signal processing have enhanced artistic control over the spatial dimension of sound..." (p. 45).

At present, there are a number of companies working

with three-dimensional audio, with Q-Sound perhaps the most prominent example.[4]

Q-Sound ostensibly allows compatibility with existing home stereo components, and allows listeners seated in the correct "sweet spot" to hear musical instruments discretely placed in sonic space. Some problems have been encountered in the initial stages of Q-Sound's marketing to the public as broadcasters who have played Q-Sound encoded compact discs have discovered that the compatibility of Q-Sound with monaural playback (through car radios or clock radios) is less than desirable (Beacham, 1991). Consumers ears' also need educating to maximize these new three-dimensional processes (Cohen, 1990).

A further dilemma for broadcasters has been the recent movement toward ending the use of analog transmission methods in favor of digital audio broadcasting (DAB). Though many broadcasters have adopted the compact disc for playback, the fidelity impact of digital recording often has been lost by sending it through an analog transmitter to an analog AM or FM radio receiver (Carter, 1990a).

But the full conversion to digital audio broadcasting for the current 10,000+ radio stations in America is likely to be costly. Some proponents have advocated establishing a separate band of frequencies exclusively for DAB. The National Association of Broadcasters already

has begun testing a system it has licensed from European digital audio broadcasters, Eureka 147, in the UHF L-band from 1500 - 1506 MHz. The FCC also has its eye on frequency bands even higher in the UHF spectrum, some near the microwave range (Gross, 1991a).

Other proponents, such as Strother Communications, have advocated establishing a national satellite-distributed system of digital audio (Carter, 1990b), a prospect with little appeal to contemporary terrestrial broadcasters. Their solution, developed and advocated by Gannett Broadcasting, would use an "in-band" version of DAB that would allow current broadcasters to simply buy a new transmitter and join the fray without establishing either a new band of competitors or losing the audio marketplace to satellite broadcasters (Gross, 1991b). Meanwhile, some cable television companies have begun offering full digital playback via cable television audio systems.

The final resolution of the DAB issue is by no means clear, though much hinges on the availability of spectrum space for a separate service which is expected to become an issue of international dimensions when it appears on the agenda of the upcoming 1992 World Administrative Radio Conference.

FOOTNOTES

[1]MIDI is useful not only to musicians working with sound, it also can be used to manipulate video images, as described by Acker (1990).

[2]This means that for every unit of noise (expressed in deciBels), there are 98 units of sound accompanying that one unit of noise. By comparison, an acceptable professional standard for audio equipment until digital equipment arrived was a S/N ratio of 55 deciBels.

[3]A number of consumer electronic manufacturers now offer a compact disc player that plays a variety of CD sizes as part of an integrated home entertainment unit.

[4]Some of the other companies involved in three dimensional audio include Ambisonics, Bedini Audio, Auris Perceptual Engineering, Crystal River Engineering, Holcphonics, Hughes Aircraft, and Pete Myers.

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